Senior Thesis

The Alliance, Ohio earthquake of August 2000: an Examination of felt reports and Surficial Deposit Correlation

by
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2002

Submitted as partial fulfillment of the
requirements for the degree of
Bachelor of Science in the
Department of Geological Sciences
at the Ohio State University,
Spring Quarter 2002

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Introduction

Earthquakes in the midcontinent are notoriously poorly studied because they are generally of small magnitudes. The waves of smaller-magnitude earthquakes are likely only to be recorded by seismic stations located a short distance from their epicenters. In order to accurately study a midcontinent low-magnitude earthquake, therefore, would require a great number of seismic stations to be installed and maintained in a perceived insignificantly active area (the midcontinent). Because the midcontinent was not traditionally considered an active area that yielded substantial seismic risk, the money was not spent to install any useful number of seismic stations. In Ohio, previous to the installation of the Ohio Seismic Network (OhioSeis), this factor meant that the source location of any earthquakes in Ohio were rarely calculated correctly, or in the case of smaller-magnitude earthquakes, recorded at all. OhioSeis has recently been launched in an effort by the Ohio Department of Natural Resources, Division of Geological Survey, to record and assess the seismic hazard risk of Ohio. OhioSeis consists of more than twenty seismic stations dispersed across the state and is beginning to gather information on smaller midcontinent earthquakes in Ohio. (Hansen, 2000, No.1)

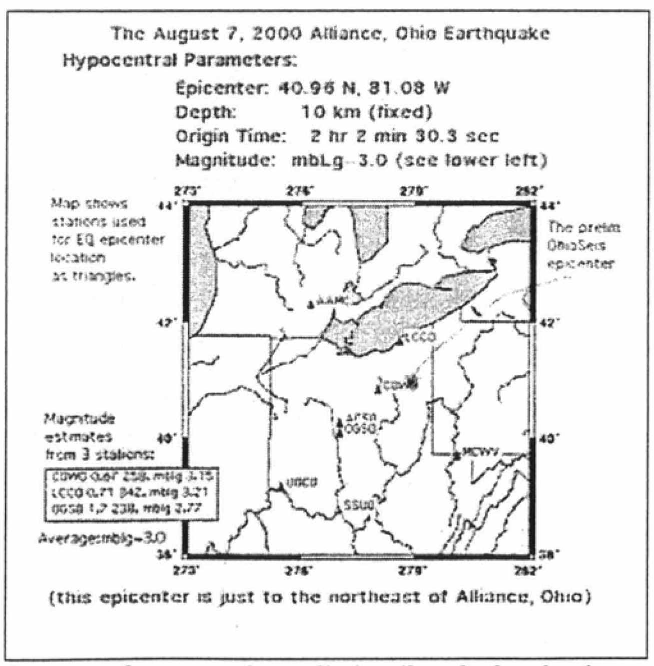


Figure A: Seismic stations in reference to the preliminarily calculated epicenter for the Alliance, Ohio earthquake of August 2000.

Source: http://aamc.geo.lsa.umich.edu/Regional_Events/00Aug7.Ohio/00Aug7.html

Among the first low-magnitude earthquakes recorded by OhioSeis was the Alliance earthquake of August 2000. By using nine seismic stations (see Figure A: Seismic stations in reference to the preliminarily calculated epicenter for the Alliance, Ohio earthquake of August 2000), the earthquake's epicenter was determined to be slightly NE of the town of Alliance, Ohio. It was also determined to have had a magnitude of 3.0 mbLg and a hypocenter depth of 10 km (Hansen, 2000, Nos. 2, 3, 4). The orientations of the recording seismic stations (in reference to the epicenter) combined with their few numbers made the calculation of a focal mechanism diagram unfeasible. To do so, recording stations in Pennsylvania would be necessary.

Low-magnitude earthquakes, such as Alliance, are vital to understanding and assessing seismic hazard risk in the midcontinent because they represent the majority of seismic activity in the region. However, simply recording magnitudes, epicenter locations, and hypocenter depths do not assess seismic hazard alone. An examination of surficial deposits is essential in determining seismic risk to humans during an earthquake of a given magnitude and location because different deposits react differently. For example, some unconsolidated deposits will liquefy more readily than others. Ohio is unlike highly active seismic areas like California, where most of the seismic surficial deposit data comes from. Glacial deposits that vary in terms of composition and thickness cover the majority of Ohio. The reactions of the types of deposits unique to Ohio are poorly understood. By examining the recorded intensity levels from felt reports of the Alliance earthquake with their corresponding surficial deposits, it is possible that some trend or correlation could be found and used in the future to delineate areas of higher seismic risk in the midcontinent. This study would be most effective in conjunction with similar studies involving other earthquakes in the midcontinent, particularly in Ohio and other states that have extensive glacial deposits, where there are the same or similar surficial deposits.

Geologic and Tectonic Setting

The Alliance earthquake is of particular note because it is one of a handful of recorded midcontinent earthquakes whose epicenter is located over a known fault zone, specifically the Suffield and Smith Township Faults (see Figure B: Map showing the epicenter of the Alliance earthquake superimposed over the Suffield and Smith Township Faults). These faults are part of the Akron-Suffield Fault Zone (also referred to as the Highland-Suffield Fault zone in the literature), which is part of the larger Transylvanian Fracture Zone (see Figure C: Map showing Transylvanian Fracture Zone). The Transylvanian Fracture Zone is a large area mainly consisting of parts of eastern Ohio and western Pennsylvania. The fracture zone is found in the Precambrian basement rocks of the Grenville Province (Root, 1988).

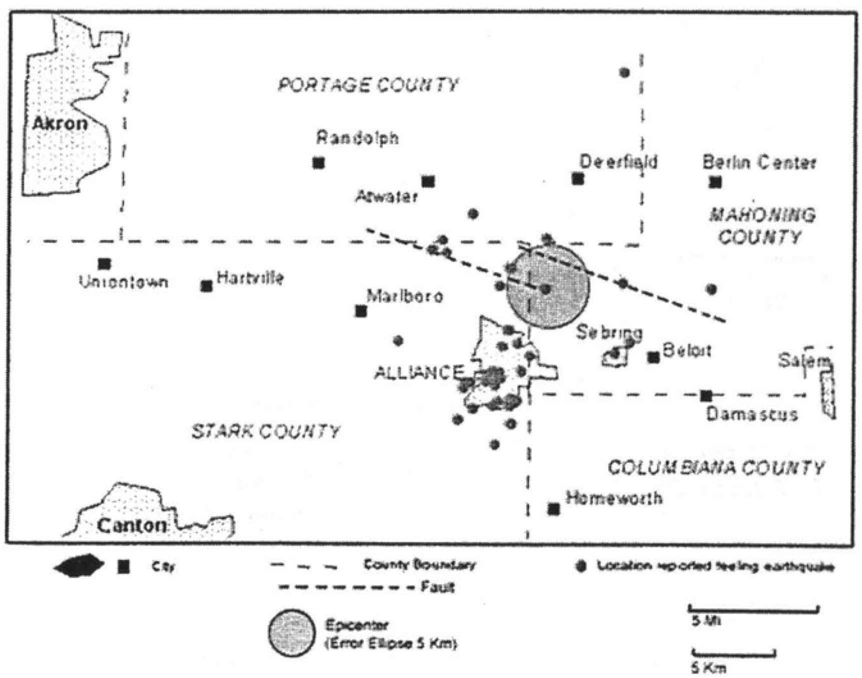


Figure B: Map showing the epicenter of the Alliance earthquake superimposed over the Suffield and Smith Township Faults

Source: http://www.dnr.state.oh.us/OhioSeis/earthquakes/000806/feltmap.gif

Historically, there have been reactivation movements along fracture surfaces of this zone. Such syndepositional movements are thought to be partially responsible for changes in the thicknesses of sedimentary basin deposits throughout the Paleozoic, which include many valuable economic units in the region such as the Pennsylvanian coals. The Akron-Suffield Fault Zone is thought to represent a right-lateral Precambrian shear zone (in the Transylvanian Fracture Zone) as evidenced by an en echelon pattern of faulting. The reactivation of the faults in this fracture zone, over geologic time, is evidenced by stratigraphic differences, among them soft sediment deformation structures in units like the Berea sandstone, known for its oil and gas deposits, which have been established using subsurface magnetic mapping data and drill-log data. Also, it is relevant to note that Paleozoic units dominate in the epicentral area of the earthquake.

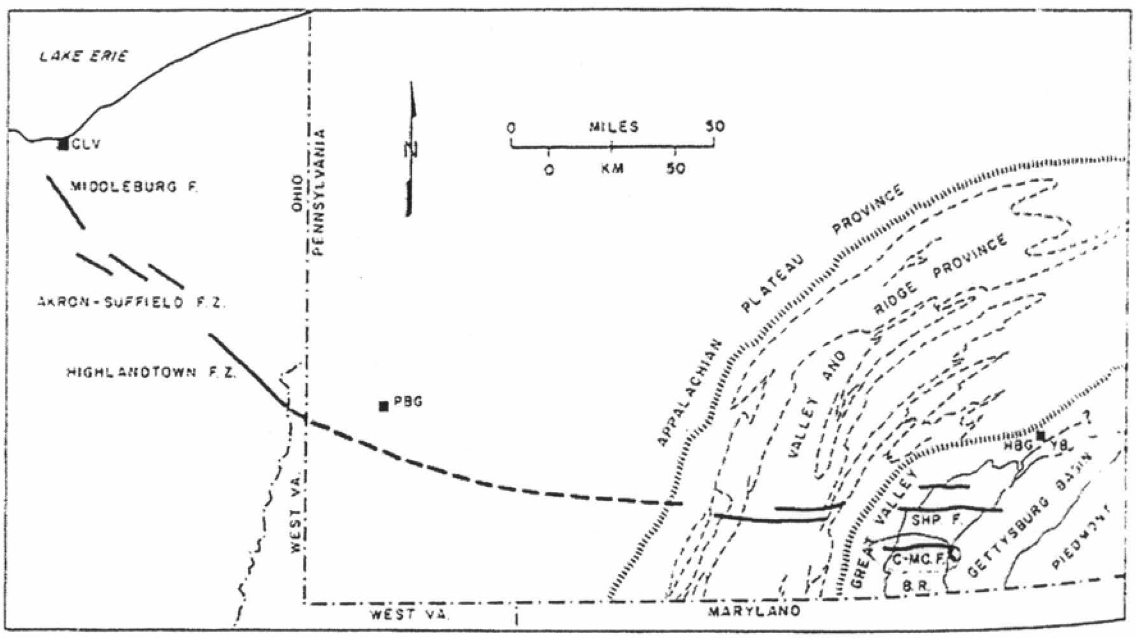


Figure C: Map showing Transylvanian Fracture Zone

Source: Root, Samuel I. "Effect of the Transylvania Fracture Zone on Evolution of the Western Margin of the Central Appalachian Basin," Proceedings of the 8th International Conference on Basement Tectonics. Vol. 8, 1988, p. 470, Figure 1.

The issue of the Alliance earthquake being located on known reactivation faults is particularly relevant because such faults have the potential to become reactivated again in the future, posing risk to humans. The calculated hypocentral depth for the earthquake is 10km, which is well into the Precambrian basement. This indicates that the earthquake was likely due to some sort of reactivation movement along a Precambrian fracture surface (see Figure D: Map of major Precambrian basement structures in Ohio). Having a better understanding of what deposits cause the greatest damage/felt intensities in earthquakes like the Alliance earthquake, will allow builders and home owners to be more aware of their risk and allow them to plan accordingly.

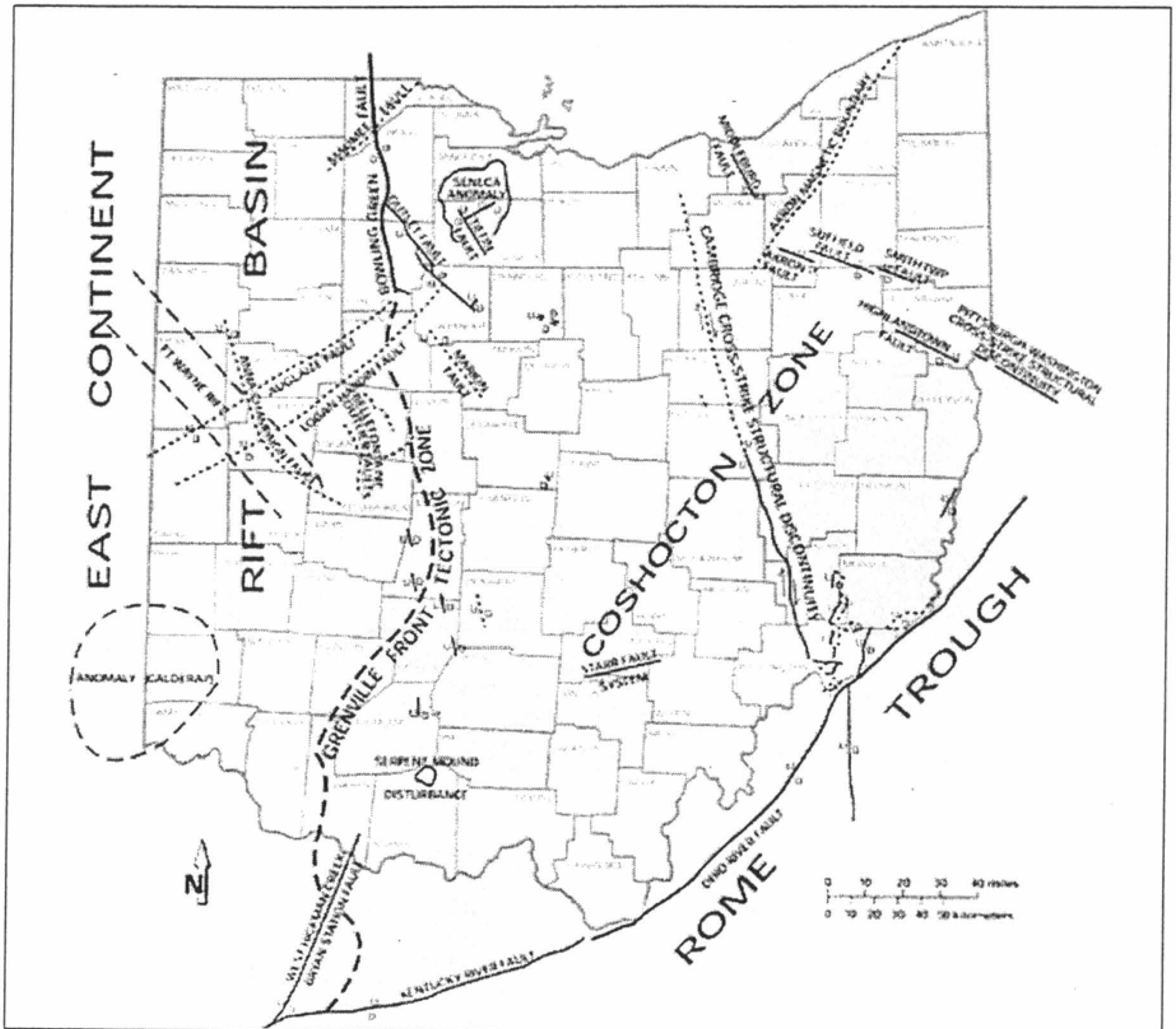


Figure D: Map of major Precambrian basement structures in Ohio.

Source: http://www.dnr.state.oh.us/OhioSeis/images/faultbig.gif

Regional Surficial Deposit Background

Various glacial deposits cover the majority of western and northeastern Ohio (see Figure E: Glacial Deposits of Ohio). The deposits are of Pre-Illinoian (> than 300,000 years), Illinoian (130,000-300,000 years), and Wisconsinan (14,000-24,000 years) in age. The till deposits vary from being sorted to unsorted, stratified to non-stratified, directly deposited to glacial outwash, etc. (Hansen, 1997).

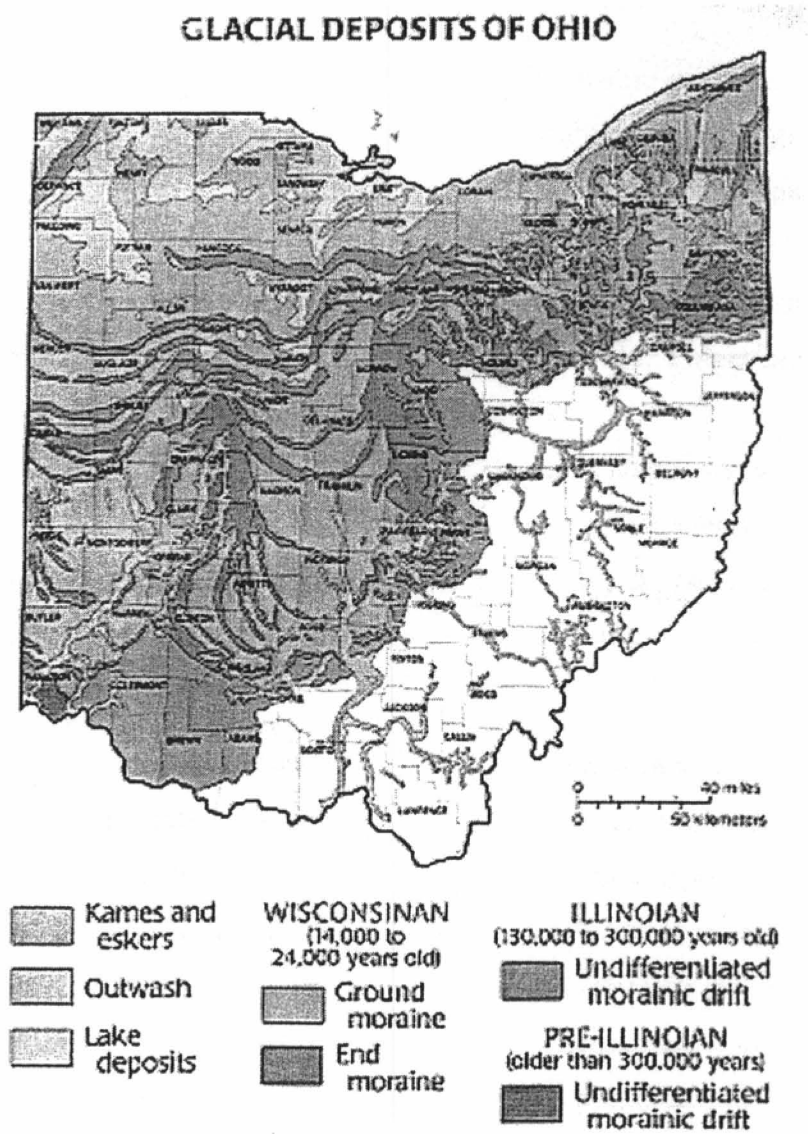


Figure E: Glacial Deposits of Ohio
Source: Hansen, Michael. "The Ice Age in Ohio," Division of Geological Survey, Educational Leaflet No. 7, 1997.

Analytical Procedure

Assigning Intensity Levels

Felt reports, previously collected by Dr. Mark McNaught and his students at Mount Union College, had been assigned Modified Mercalli Intensities. For the purposes of this study, the felt reports were reevaluated against the Modified Mercalli Intensity Scale to yield the following criteria within the language of the felt reports themselves:

I. Same language as Modified Mercalli Scale (see Appendix A: Modified Mercalli Scale).

II. Felt something, but not enough to have any visible evidence.

III. Definitely felt something and had visible (rattling or shaking) or aural evidence, yet still not enough to give the event more than a passing thought.

IV. Everyone definitely felt and heard it, comparing it to a truck hitting the house or to an explosion. Objects often displaced. Powerful enough that people felt the need to investigate the source.

Overall, few changes were made from the original McNaught analysis and assignment of intensity levels. Due to the inherent vagueness of felt reports, some reports were additionally given a + or –, within the Modified Mercalli Scale divisions to more accurately indicate report intensity levels for future investigations.

Preliminary Plotting of Felt Reports

The felt reports already had decimal latitude/longitude locations assigned to them, which were presumed accurate for this study. The locations were individually entered into the Topozone program online, which located the reports on a topographic map (1:200,000 and 1:100,000 scales). The locations were transferred from their plotted points on the topographic map to a surficial deposits map (1:250,000 scale). Because of the map scale and landmark differences, felt reports that were close to a border between surficial deposits were assigned a primary and secondary surficial deposit for the data set. For an explanation of the surficial deposits of the preliminary plotting, see Appendix B: Preliminary Surficial Deposit Nomenclature.

Secondary Plotting of Felt Reports

In order to increase data resolution, the felt report locations were plotted on a second set of, unpublished to date, surficial deposit maps. These maps are part of an initiative by the Ohio Geological Survey to remap the surficial deposits of Ohio (see reference list for NE Portion of the Surficial Geology of the Canton 30 x 60 minute Quadrangle). They correspond to existing quadrangle maps published by the ODNR Division of Geological Survey.

Using the same previously assigned latitude/longitude locations of the felt reports, each report site was located on a 7.5 minute topographic map by using the Topozone program (this time at the 1:25,000 scale). The locations were then plotted on a mylar sheet over standard topographic quadrangle maps, 1: 24,000 scale, each quad having its own mylar sheet. Each mylar sheet was then laid over its corresponding surficial deposit map (same scale as quad), and its deposit type recorded.

Reassigning Surficial Deposits for Data Analysis

The surficial deposit data collected using the felt reports had to be grouped in reassigned types of surficial deposits because there were 32 technically 'different' types of surficial deposits due to a number of varying possible combinations of deposit types and thicknesses. See Appendix C for explanation of the surficial deposit nomenclature used by the authors of the surficial deposit quad maps. Patchy deposits were ignored as being insignificant due to their inconsistent nature. Deposits with an average thickness of less than 25' were also regarded as having insignificant influence, and thus were disregarded when reassigning. The top deposit was designated as 1st deposit and the deposit below the first was designated the 2nd deposit, and so on. If there was only one deposit above bedrock, and that deposit was 25' or greater in thickness, then that deposit was assigned as that deposit type for the given felt report. For example, if the deposit was T8 / P, with an average thickness of 80', that deposit would be placed in the TILL surficial deposit category. T2 / P, on the other hand would be placed in the BEDROCK category because its average thickness is only 20'. If the 1st deposits had an equally significant 2nd deposit, then that deposit would be reassigned to recognize both deposits. For example, T4 / IC20- / P, with an average till thickness of 40' and an average ice contact deposit thickness of 100', would be designated as T-IC. The felt reports with corresponding reassigned surficial deposits were totaled according to their corresponding Modified Mercalli Scale Intensity Level.

Isoseismal Map

Some felt reports had been given a + or – in addition to their assigned Modified Mercalli Intensity level. These designations were considered when creating an isoseismal map of the plotted (on mylar) felt reports. That is to say, that when examining a cluster of points, if all of them were IV's except for a III+, the III+ would be used to indicate that the III+ is likely a IV in reality, and would therefore be included as such in creating the lines of intensity divisions. The epicenter and error ellipse were also plotted on the isoseismal map for reference.

Results

Data Table in Felt Report Number Order

Histogram 1:	Preliminary Plotting Mercalli Scale and Corresponding Surficial Deposits
Histogram 2:	Preliminary Plotting Surficial Deposits and Corresponding Mercalli Scale

Reassigned Surficial Deposit Summary Data Table

Histogram 3:	Secondary Plotting Mercalli Scale and Corresponding Surficial Deposits
Histogram 4:	Secondary Plotting Surficial Deposits and Corresponding Mercalli Scale

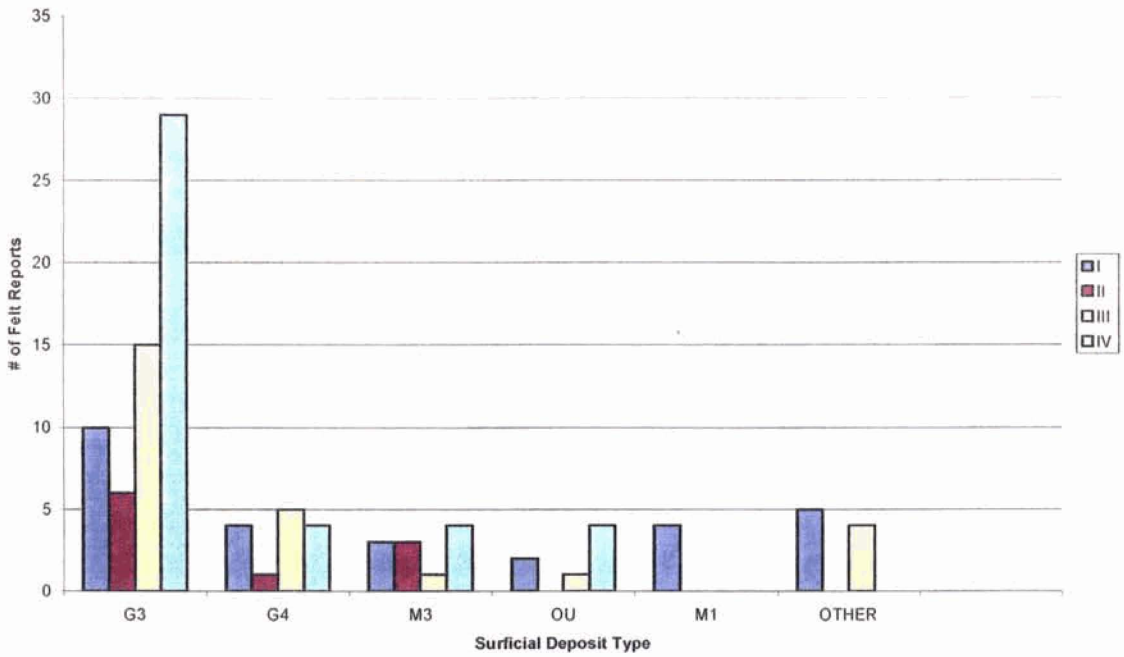
Modified Mercalli Scale	Intensity Level in Mercalli	ID #		Latitude		Longitude	Building Type	Building Material	SD (1)	Could be	Surficial Deposit (2)	Quad
III		2	N	40.90317	W	81.14156	APARTMENT		G3	M3	T4 / IC18- / P	LIMAVILLE
IV		3	N	40.89712	W	81.09996	SF HOME	WOOD	M3	OU	T7- / SGd15- / P	ALLIANCE
IV		4	N	40.89955	W	81.10232	SF HOME		G3	M3	T2 / P	ALLIANCE
IV		5	N	40.93004	W	81.10261	SF HOME	WOOD	G3		T2 / P	ALLIANCE
IV		6	N	40.96192	W	81.11155	SF HOME	WOOD	G4		T7- / SGd9- / P	ALLIANCE
III		7	N	40.90858	W	81.13694	SF HOME	BRICK	G3		T4 / IC18- / P	LIMAVILLE
IV		8+9	N	40.90032	W	81.09525	CABIN	WOOD	G3	M3	T2 / P	ALLIANCE
IV		10	N	40.90849	W	81.10768	SF HOME	BRICK	G3		T2 / P	ALLIANCE
IV		11	N	40.93349	W	81.10393	SF HOME	WOOD	G3		SG2 / SGd6- / P	ALLIANCE
III		12	N	40.95184	W	81.06989	SF HOME		G4		MINE	ALLIANCE
IV	-	13	N	40.91663	W	81.1093	SF HOME	BRICK	G3		T2 / P	ALLIANCE
II		14	N	40.92429	W	81.02162	APARTMENT	BRICK	G4		T7- / SGd3 / T7- / P	ALLIANCE
III		15	N	40.90852	W	81.1087	APARTMENT	BRICK	G3		T2 / P	ALLIANCE
IV		16	N	40.9271	W	81.10708	APARTMENT	WOOD	G3		T2 / P	ALLIANCE
III	-	17	N	40.93004	W	81.1868	SF HOME	BRICK	G3		(T) / P	LIMAVILLE
IV		18	N	40.90828	W	81.11285	SF HOME	BRICK	G3		T2 / P	ALLIANCE
IV		19	N	40.90669	W	81.11082	SF HOME		G3		T2 / P	ALLIANCE
III		20	N	40.8954	W	81.10197	SF HOME	BRICK	M3		T7- / SGd15- / P	ALLIANCE
II		21	N	40.87202	W	81.11313	SF HOME	BRICK	M3		T6 / P	HOMEWORTH
III		22	N	40.98362	W	81.14699	SF HOME	WOOD	G3		(T2) / SGd11- / P	LIMAVILLE
III		23	N	40.98649	W	81.06954	SF HOME	WOOD	G4		T6 / P	ALLIANCE
IV		24	N	40.92954	W	81.01317	SF HOME	WOOD	OU	M4	SG2 / SGd17- / P	ALLIANCE
IV		25	N	40.91433	W	81.10986	SF HOME	WOOD	G3		T2 / P	ALLIANCE
IV		26	N	40.88691	W	81.14504	RANCH	WOOD	M3		T4 / IC18- / P	LIMAVILLE
IV	-	27	N	40.89199	W	81.12935	SF HOME		G3		T6 / P	LIMAVILLE
IV		28	N	40.88637	W	81.10181	SF HOME	WOOD	M3		T7- / SGd15- / P	ALLIANCE
IV		29	N	40.98304	W	81.14762	SF HOME	WOOD	G3		(T2) / SGd11- / P	LIMAVILLE
IV		30	N	40.98441	W	81.14702	SF HOME	WOOD	G3		T5- / SGd19- / P	LIMAVILLE
I		31	N	40.8585	W	80.9889	SF HOME	WOOD	M3		IC16- / P	HANOVERTON
III		32	N	41.0861	W	81.012	SF HOME	WOOD	G4		T7 / SG2 / SSh	DEERFIELD
IV		33	N	40.91553	W	81.09624	SF HOME	BRICK	G3		T2 / P	ALLIANCE
IV		34	N	40.90826	W	81.11719	SF HOME	WOOD	G3		T2 / P	ALLIANCE
III	+	35	N	40.90768	W	81.10621	SF HOME	BRICK	G3		T2 / P	ALLIANCE
IV		36	N	40.96038	W	81.0127	SF HOME	BRICK	G4		T6 / P	ALLIANCE

Modified Mercalli Scale	Intensity Level in Mercalli	ID #		Latitude		Longitude	Building Type	Building Material	SD (1)	Could be	Surficial Deposit (2)	Quad
Modified Mercalli Scale	Intensity Level in Mercalli	ID #		Latitude		Longitude	Building Type	Building Material	SD (1)	Could be	Surficial Deposit (2)	Quad
III	+	37	N	40.91298	W	81.11748	SF HOME	BRICK	G3		T2 / P	ALLIANCE
III		38	N	40.95935	W	80.95235	SF HOME	BRICK	M4	K	(T2) / IC7- / P	DAMASCUS
IV		39	N	40.97488	W	81.10183	SF HOME	WOOD	G4		T7- /SGd9- / P	ALLIANCE
IV		40	N	40.89731	W	81.10584	APARTMENT	BRICK	G3		T2 / P	ALLIANCE
IV		41	N	40.90854	W	81.11251	SF HOME	BRICK	G3		T2 / P	ALLIANCE
III	-	42	N	40.89723	W	81.10923	SF HOME	WOOD	G3		T2 / P	ALLIANCE
I		43	N	40.91401	W	81.01927	SF HOME	WOOD	OU		(SG) / T5- / P	ALLIANCE
IV		44	N	40.92244	W	81.09113	SF HOME	WOOD	G3		T2 / P	ALLIANCE
III	+	45	N	40.99265	W	81.12375		BRICK	G4		T3 / SGd10- / P	ALLIANCE
I		46	N	40.90686	W	81.11288	SF HOME	BRICK	G3		T2 / P	ALLIANCE
I		47	N	40.99424	W	81.19532	SF HOME	WOOD	G3		T4- / (IC4) / P	LIMAVILLE
I		48	N	40.89955	W	81.11204	SF HOME	WOOD	G3		T2 / P	ALLIANCE
I		49	N	40.90532	W	81.09866	SF HOME		G3		T2 / P	ALLIANCE
I		50	N	41.0837	W	81.1702	RANCH	WOOD	G3		T9- / IC14- / P	ATWATER
IV	+	51	N	40.93748	W	81.08462	RANCH	WOOD	G4		T8- / SGd17- / P	ALLIANCE
IV		52	N	40.92933	W	81.2054	RANCH	WOOD	M3		T3 / IC12- / P	LIMAVILLE
III	-	53	N	40.94553	W	81.16212			G3		T4- / SGd9- / P	LIMAVILLE
IV		54	N	40.91755	W	81.11363	SF HOME	WOOD	G3		T2 / P	ALLIANCE
III	+	55	N	40.91753	W	81.10886	SF HOME	WOOD	G3		T2 / P	ALLIANCE
III		57	N	40.90268	W	81.10622	SF HOME	WOOD	G3		T2 / P	ALLIANCE
IV		58	N	40.89777	W	81.10923	SF HOME	BRICK	G3		T2 / P	ALLIANCE
IV		59	N	40.92017	W	81.11412	SF HOME	WOOD	G3		T2 / P	ALLIANCE
IV		60	N	40.90901	W	81.106	SF HOME	BRICK	G3		T2 / P	ALLIANCE
IV	+	61	N	40.90553	W	81.11386	APARTMENT	BRICK	G3		T2 / P	ALLIANCE
III	-	62	N	41.0064	W	81.0677	SF HOME		G4		T3 / SSh	DEERFIELD
I		63	N	40.82901	W	81.23779	SF HOME	BRICK	G1		(T2) / IC14- / P	ROBERTSVILLE
I		64	N	40.8435	W	81.3621	RANCH	BRICK	G1			(CANTON EAST)
I		65	N	40.90077	W	81.33491	SF HOME	WOOD	M1			(HARTVILLE)
I		66	N	40.8552	W	81.4273	MALL		K			(CANTON WEST)
I		67	N	40.82816	W	80.89833	SF HOME	WOOD	M1		(T) / (Ti) / P	HANOVERTON
IV	-	68	N	40.92002	W	81.12417	SF HOME	BRICK	G3		T2 / P	ALLIANCE

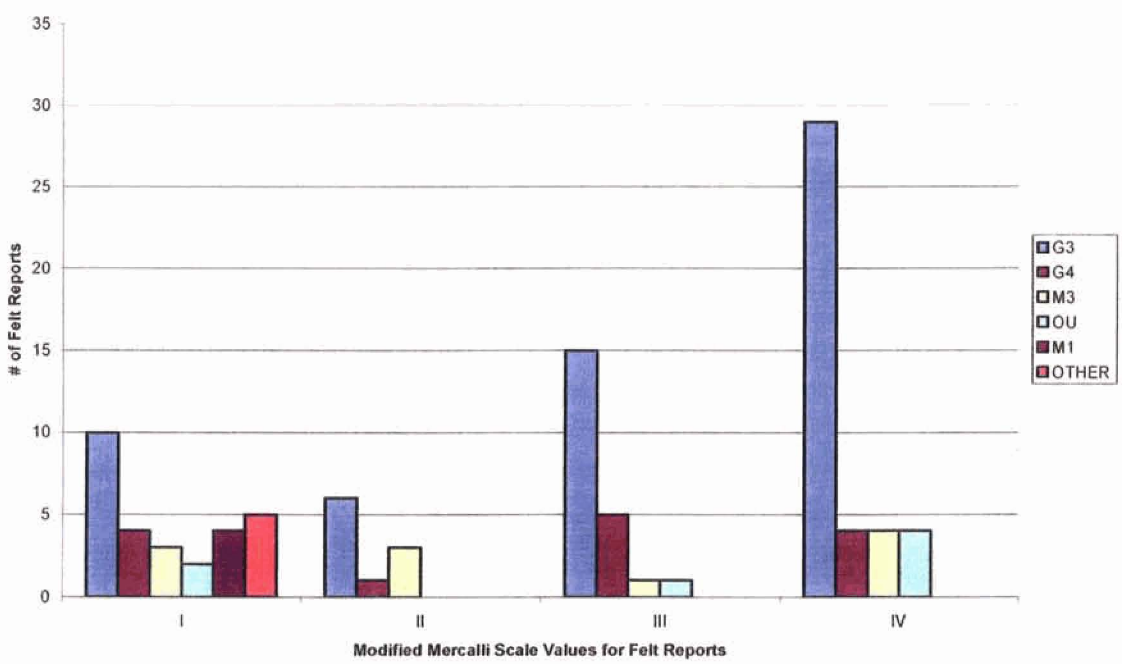
Modified Mercalli Scale	Intensity Level in Mercalli	ID #		Latitude		Longitude	Building Type	Building Material	SD (1)	Could be	Surficial Deposit (2)	Quad
Modified Mercalli Scale	Intensity Level in Mercalli	ID #		Latitude		Longitude	Building Type	Building Material	SD (1)	Could be	Surficial Deposit (2)	Quad
II	-	69	N	40.88682	W	81.12522	SF HOME	WOOD	M3		T6 / P	ALLIANCE
IV		70	N	40.89991	W	81.10373	SF HOME	WOOD	G3		T2 / P	ALLIANCE
III	-	71	N	40.89337	W	81.10756	SF HOME	WOOD	G3		T7- / SGd15- / P	ALLIANCE
IV		72	N	40.94476	W	81.10094	OFFICE	WOOD	OU	G4	T8- / SGd17- / P	ALLIANCE
III		73	N	40.92429	W	81.02348	DUPLEX	WOOD	LC		T7- / SGd3 / T7- / P	ALLIANCE
III		74	N	40.95141	W	81.22665	SF HOME	WOOD	UX		T6 / P	LIMAVILLE
IV	-	75	N	40.90637	W	81.1148	SF HOME	BRICK	G3		T2 / P	ALLIANCE
I		76	N	40.89738	W	81.10608	RANCH	BRICK	G3		T2 / P	ALLIANCE
IV		77	N	40.90935	W	81.10338	SF HOME	WOOD	G3		T2 / P	ALLIANCE
I		78	N	40.89725	W	81.10617	RANCH	BRICK	G3		T2 / P	ALLIANCE
IV	+	79	N	40.93167	W	81.0866	SF HOME	WOOD	OU		(T) / SG2 / SGd17- / P	ALLIANCE
III	+	80	N	40.96119	W	81.1852	SF HOME		G3		T2 / P	LIMAVILLE
I		81	N	41.0181	W	81.2483	SF HOME	WOOD	UX		IC27- / P	ATWATER
II	+	82	N	40.91405	W	81.10236	SF HOME	WOOD	G3		T2 / P	ALLIANCE
II	+	83	N	40.90633	W	81.11371	SF HOME	WOOD	G3		T2 / P	ALLIANCE
IV		84	N	40.9313	W	81.11644	SF HOME	WOOD	G3		T2 / P	ALLIANCE
II		85	N	40.98124	W	81.14812	SF HOME	WOOD	G3		(T2) / SGd11- / P	LIMAVILLE
I		86	N	40.82601	W	80.98996	SF HOME	WOOD			IC19- / P	HANOVERTON
II	+	87	N	40.983	W	81.14971	SF HOME	WOOD	G3		(T2) / SGd11- / P	LIMAVILLE
I		88	N	40.91562	W	81.12107	SF HOME	BRICK	G3		T2 / P	ALLIANCE
I		89	N	40.89708	W	81.10233	SF HOME		G3		T7- / SGd15- / P	ALLIANCE
I		90	N	40.90948	W	81.10193	SF HOME	WOOD	G3		T2 / P	ALLIANCE
I		91	N	40.85135	W	81.1043	SF HOME		M1		T6 / P	HOMEWORTH
I		92	N	40.8915	W	81.1274			M3		T6 / P	LIMAVILLE
I		93	N	40.88577	W	81.91532	SF HOME					(CRESTON)
II		94	N	40.98681	W	81.1482	SF HOME	WOOD	G3		T5- / SGd19- / P	LIMAVILLE
III		95	N	40.9857	W	81.14814	SF HOME	WOOD	G3		T5- / SGd19- / P	LIMAVILLE
III	-	96	N	40.98819	W	81.15388	SF HOME	WOOD	G3		T8 / P	LIMAVILLE
I		97	N	40.90189	W	81.13281	SF HOME	BRICK	M3		T6 / P	LIMAVILLE
I		98	N	40.85215	W	81.28178	APARTMENT	BRICK	M1			(CANTON EAST)
I		99	N	41.1091	W	81.0508	SF HOME		G4		T3 / SSh	DEERFIELD

Modified Mercalli Scale	Intensity Level in Mercalli	ID #		Latitude		Longitude	Building Type	Building Material	SD (1)	Could be	Surficial Deposit (2)	Quad
Modified Mercalli Scale	Intensity Level in Mercalli	ID #		Latitude		Longitude	Building Type	Building Material	SD (1)	Could be	Surficial Deposit (2)	Quad
IV	-	100	N	40.89779	W	81.10923	SF HOME	BRICK	G3		T2 / P	ALLIANCE
II		101	N	40.90197	W	81.1766	SF HOME	BRICK	M3		T4 / IC20- / P	LIMAVILLE
I		102	N	40.946	W	81.31546	SF HOME	BRICK	K			(HARTVILLE)
II		103	N	40.91538	W	81.11184	DUPLEX	WOOD	G3		T2 / P	ALLIANCE
I		104	N	40.91547	W	81.02035	SF HOME		G4		(SG) / T5- / P	ALLIANCE
III	+	105	N	40.82333	W	81.2363	SF HOME	BRICK	G1		(T2) / IC14- / P	ROBERTSVILLE
I		106	N	40.98441	W	80.94909			G4		IC17- / P	DAMASCUS
I		107	N	40.90137	W	80.96478	SF HOME		G4		SG2 / SGd17- / P	DAMASCUS
I		109	N	40.9106	W	81.07834	SF HOME	WOOD	OU		(T2) / SG2 / SGd17- / P	ALLIANCE
III		110	N	40.91439	W	81.07843	SF HOME		OU		(T2) / SG2 / SGd17- / P	ALLIANCE
IV	+	111	N	40.93356	W	81.09958	SF HOME	WOOD	OU		T8- / SGd17- / P	ALLIANCE

Preliminary Surficial Deposits Corresponding to Modified Mercalli Scale Felt Reports for the Alliance, OH Earthquake



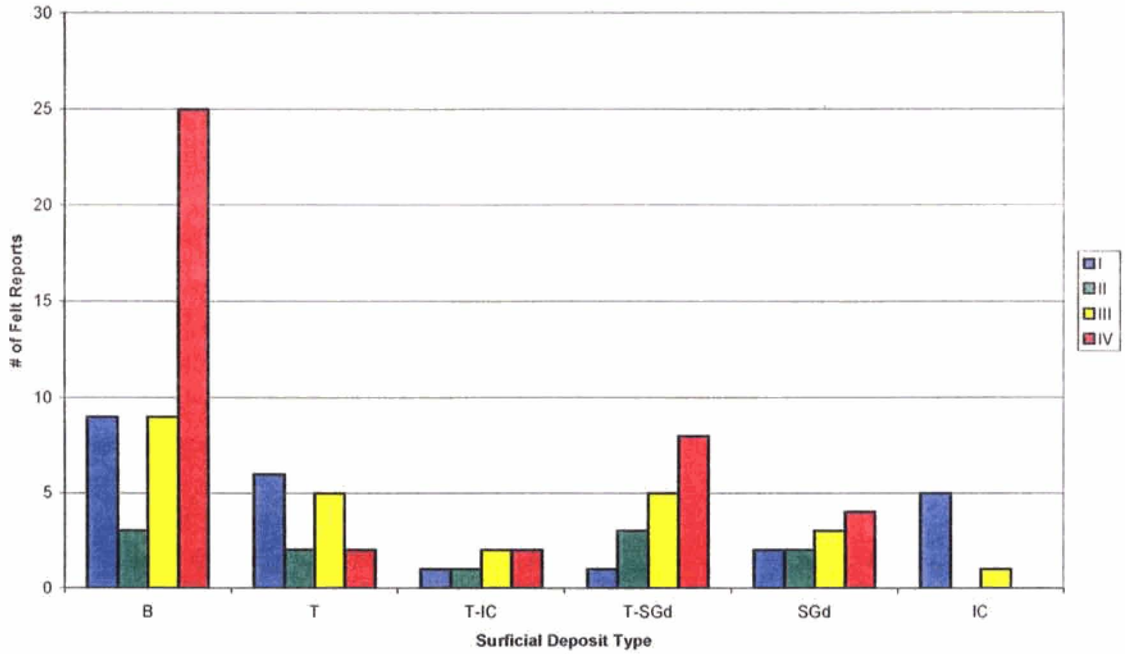
Modified Mercalli Felt Reports and their Corresponding Preliminary Surficial Deposits for the 2000 Alliance, Ohio Earthquake



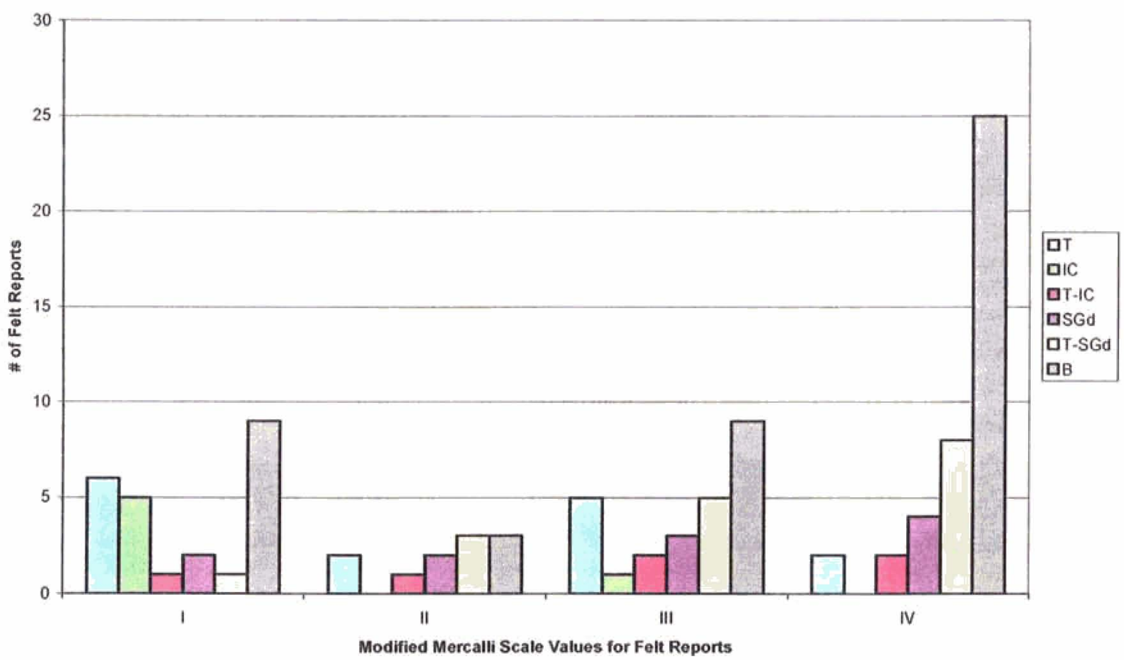
Alliance Earthquake
August 2000

Map Assigned Surficial Depot		1st Depot Thickness Range	Ave		2nd Depot Thickness Range	Ave 2nd Depot	Depot	3rd Depot Thickness Range	Ave 3rd Depot	Assigned Dominant Depot	Mod. Mercalli Int. I	II	III	IV
MINE	B			B						BEDROCK	0	0	1	0
(T) / (TI) / P	T	IGNORED		TI	IGNORED					BEDROCK	1	0	0	0
(T) / P	T	IGNORED		B						BEDROCK	0	0	1	0
T2 / P	T	10-30	20	B	0					BEDROCK	7	3	7	25
T4- / (IC4) / P	T	0-40	20	IC	IGNORED					BEDROCK	1	0	0	0
											9	3	9	25
T3 / SSh	T	15-45	30	B	0					TILL	1	0	2	0
(SG) / T5- / P	SG	IGNORED		T	0-50	25				TILL	2	0	0	0
T6 / P	T	30-90	60	B	0					TILL	3	2	2	2
T8 / P	T	40-120	80	B						TILL	0	0	1	0
											6	2	5	2
T3 / IC12- / P	T	15-45	30	IC	0-120	60				T-IC	0	0	0	1
T4 / IC18- / P	T	20-60	40	IC	0-180	90				T-IC	0	0	2	1
T4 / IC20- / P	T	20-60	40	IC	0-200	100				T-IC	0	1	0	0
T9- / IC14- / P	T	0-90	45	IC	0-140	70				T-IC	1	0	0	0
											1	1	2	2
T5- / SGd19- / P	T	0-50	25	SGd	0-190	95				T-SGd	0	1	1	1
T7- / SGd9- / P	T	0-70	35	SGd	0-90	45				T-SGd	0	0	0	1
T7- / SGd3 / T7- / P	T	0-70	35	SGd	20-40	30	T	0-70	35	T-SGd	0	2	0	0
T7- / SGd15- / P	T	0-70	35	SGd	0-150	75				T-SGd	1	0	2	3
T7 / SG2 / SSh	T	35-105	70	SGd	10-30	20				T-SGd	0	0	1	0
T8- / SGd17- / P	T	0-80	40	SGd	0-170	85				T-SGd	0	0	0	3
T3 / SGd10- / P	T	15-45	30	SGd	0-100	50				T-SGd	0	0	1	0
											1	3	5	8
T4- / SGd9- / P	T	0-40	20	SGd	0-90	45				SGd	0	0	1	0
(T2) / SGd11- / P	T	IGNORED		SGd	0-110	55				SGd	0	2	1	1
SG2 / SGd6- / P	SG	10-30	20	SGd	0-60	30				SGd	0	0	0	1
SG2 / SGd17- / P	SG	10-30	20	SGd	0-170	85				SGd	1	0	0	1
(T) / SG2 / SGd17- / P	T	IGNORED		SG	10-30	20	SGd	0-170	85	SGd	0	0	0	1
(T2) / SG2 / SGd17- / P	T	IGNORED		SG	10-30	20	SGd	0-170	85	SGd	1	0	1	0
											2	2	3	4
(T2) / IC7- / P	T	IGNORED		IC	0-70	35				IC	0	0	1	0
(T2) / IC14- / P	T	IGNORED		IC	0-140	70				IC	1	0	0	0
IC16- / P	IC	0-160	80	B						IC	1	0	0	0
IC17- / P	IC	0-170	85	B						IC	1	0	0	0
IC19- / P	IC	0-190	95	B						IC	1	0	0	0
IC27- / P	IC	0-270	135	B						IC	1	0	0	0
											5	0	1	0

Secondary Surficial Deposits and Corresponding to Modified Mercalli Scale Felt Reports for the 2000 Alliance, OH Earthquake



Modified Mercalli Felt Reports and Corresponding Secondary Surficial Deposits for the 2000 Alliance, Ohio Earthquake



Discussion

Subjectivity of Felt Reports

There is an innate vagueness of felt reports that makes the process of assigning intensity levels rather arbitrary. The people who submitted the felt reports were not consistent and described things differently, making it difficult to decide which descriptions constituted which particular intensities. As previously described in the analysis section of this report, an attempt was made to use any consistencies present in the felt reports to establish a uniform standard.

Another factor to consider is the subjectivity of the felt reports and the questions they ask. For example, a skittish person, or someone who was awakened by the event, might have found the event to be very intense and long in duration, though in reality it might not have been as strong as they perceived it to be. Many of the people who filled out felt reports are non-scientifically oriented, much less seismically oriented, which often distorts their descriptions. Their reports tend to be either exaggerated or minimized, according to their perception of the event, as most people had nothing to compare the event to. Interestingly though, a few felt reporters compared the Alliance quake of 2000 to another more intense earthquake that had occurred some years ago in the same region. Those reports that contained a comparison, likely provided a less biased interpretation of earthquake intensity.

It is also important to note that the felt report form used in this study was not the complete USGS standard earthquake report form. Two questions were left out, and these could have possibly changed the intensity level interpretation of several felt reports. The first, and more relevant one being, "How would you best describe your reaction? (Don't remember/no answer; No reaction/not felt; Very little reaction; Excitement; Somewhat frightened; Very frightened; Extremely frightened)." The second being, "How did you respond? (Don't remember/no answer; Took no action; Moved to doorway; Ducked and covered; Ran outside; Other)." It is likely that the second question would have proved to be unhelpful because of the low magnitude of the earthquake. Most people would have likely chosen either the 'don't remember/no answer' or 'took no action' response. But perhaps those respondents, who noted that they ran outside to see if a car hit their house, would have selected the 'ran outside' response, making it easier to discern different intensities.

Conclusions of Preliminary Plotting

There was a strong indication that there was a correlation of the G3 deposit with higher intensities, but that appeared likely to be due to the magnified error effect/bias from the majority of the felt reports being located in the town of Alliance (on one deposit). There was also a vagueness of the surficial deposit map used in designating surficial deposits due to the map's large scale and non-detailed oriented/lumping nature. There is also an indication of inadequate sampling of felt reports because of the concentration of felt reports in the town of Alliance. After the time of this initial plotting of felt reports, a new set of currently unpublished more detailed, smaller scaled, surficial deposit maps became available for plotting. The next logical step was to plot the points on these new maps to look for more realistic correlations.

Conclusions of Secondary Plotting

Both bedrock and T-SGd seemed to show a trend of reacting with higher intensity levels. However, the inadequate sampling of the felt reports became painfully obvious in this round of plotting. The epicenter is located in an area of open farmland, so felt reports became concentrated on given deposits, because the only people available to give felt reports were concentrated in nearby towns (all in Alliance, Limaville, etc.). Most of the clusters consisted of the whole spectrum of intensity levels for this earthquake, from I to IV. This closely packed variation, again, indicated an overall inconsistency and inaccuracy of the felt reports.

Isoseismal Map

There were no apparent correlations between the isoseismic polygons and the surficial deposit polygons. However, due to the inadequate sampling of felt reports used in the creation of the isoseismal map, there is a certain amount of arbitrary delineation that should be noted. That is to say, the sparseness of the given sampling of felt reports obscures the presence of any potentially existing correlations.

Conclusions and Future Studies

In the grander scheme of things, this study could be used in conjunction with other similar studies of 3.0 (small) magnitude earthquakes in the future to predict how a given surficial deposit would react with which intensity level given a 3.0 (small) magnitude earthquake. The data does show, however limited, an indication that the deposit T-SGd and bedrock reacted to the 3.0 magnitude earthquake with higher Modified Mercalli scale intensity levels. More similar studies are necessary to draw any substantial conclusions. Combining the data from this study with the data from other studies seems critical to drawing any useful conclusions, considering the primary problem with the data was inadequate sampling. Perhaps future studies could take a more statistical approach to the felt report data and take into account the unequal distribution of the felt reports. The town-cluster bias may or may not be removable or made negligible by applying statistical techniques to the data set. However, it would also likely be easier to remove the clustering bias with a larger sample population.

Along similar lines, in the future, it might be useful to take into account the distance of the felt reports to the center of the error ellipse. If there are a large number of felt reports on deposit A, but they are located far away from the epicenter, they could skew the results by making it appear that deposit A reacted to the earthquake with low intensity levels. That would require the establishment of arbitrary cut off distances, but those distances could be determined reasonable given the magnitude of the earthquake.

Future studies that involve the collection of felt reports need to take a more proactive approach to collecting the felt reports. There are several factors critical to getting more accurate, reasonable results. They are the same as the factors that make for a good crime witness: timeliness and dependability. The witness statements have to be collected within a day or two to reduce the effects of memory loss/distortion and bias from the influence of outside sources (ie-the news said there was an earthquake, so I must have felt it). At the same time however, a high volume of felt reports is needed to make a more accurate interpretation. Unless there is a force of numerous people on hand to canvas the area surrounding the epicenter for felt reports, the event has to get a lot of media coverage (news and local newspapers) so that when the potential felt reporter receives the actual report form they will know what it is all about and are therefore more likely to fill it out. As for dependability, that is rather subjective, and unless the witnesses are being interviewed face to face, it is unlikely that this aspect can be established. Theoretically though, the unreliable reports should be easy to weed out when the felt reports and their intensities are plotted (an errant I in a large cluster of III's).

From a more structural perspective, it would perhaps be useful for seismometers to be set up throughout the surrounding area of the Suffield and Smith Township Faults. Since the Alliance earthquake is thought to represent reactivation along one of those faults, it is likely that one or both will be reactivated in the future. The presence of many seismometers would allow for an even smaller error ellipse to be created. Also the presence of many seismometers would result in many seismograms of any future earthquakes being produced. These seismograms could be used to create focal mechanism diagrams, which would determine the local contemporary stress regime of Northeast Ohio, and which could be used with others to see the bigger picture of the contemporary stress regime of the midcontinent. Once the stress regime is better understood, seismologists could better predict which faults have a higher chance of becoming reactivated under the current stress regime. However, considering the rarity of the earthquakes in this area (movement along such faults), the time and expense that such a program would require makes such an investigation impractical.

Acknowledgements

I would like to thank Michael C. Hansen, *Ohio Geological Survey*, for all the time he took out of his busy schedule running OhioSeis to guide me through this thesis from its beginnings of data collection and analysis to its final review and completion.

I would like Glenn E. Larsen, *Ohio Geological Survey*, for providing insight on how to approach the data when looking for isoseismal trends and sources for trends.

Also, I would like to thank Glenn and E. Mac Swinford, *Ohio Geological Survey*, for letting me use their unpublished surficial deposit maps and helping me to understand the methodology behind them.

I would like to thank Hallan C. Noltimier, *The Ohio State University*, for being willing to serve as a co-advisor on this project so that I could work on a 'real-world' geological problem at the Ohio Geological Survey.

I would like to thank Mark McNaught, *Mt. Union University*, for collecting the felt report data and permitting me to use it as a basis for my investigation.

Finally, I would like to give a special thanks to Thomas A. Marker II, *The Ohio State University*, for all the hours he spent putting together the figures for my thesis and reviewing my written thesis.

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Appendix A:
Modified Mercalli Scale

I	Detected only by sensitive instruments
II	Felt only by a few persons at rest, especially on upper floors of buildings; delicately suspended objects may swing
III	Felt noticeably indoors, especially on upper floors of buildings, but not always recognized as earthquake; standing autos may rock slightly; vibrations like a passing truck
IV	During the day, felt indoors by many, outdoors by few; at night, some awakened; dishes, windows, doors disturbed; walls make creaking sound; sensation like heavy truck hitting building; standing autos rock noticeably
V	Felt by most people; some breakage of dishes, windows, and plaster; unstable objects overturned; disturbance of trees, poles, and other tall objects
VI	Felt by all, many frightened and run outdoors; some heavy furniture may move; falling plaster and chimneys, damage slight
VII	Everyone runs outdoors; damage to buildings varies depending on quality of construction; noticed by people driving autos
VIII	Panel walls thrown out of frames; walls, monuments, chimneys fall; sand and mud ejected; drivers of autos disturbed
IX	Buildings shifted off foundations, frame structures thrown out of plumb; ground cracked; underground pipes broken
X	Most masonry and frame structures destroyed; ground badly cracked, rails bent, landslides; sand and mud shift; water splashes over river banks
XI	Few structures remain standing; bridges destroyed; broad fissures in ground, pipes broken, landslides, rails bent
XII	Damage total; waves seen on ground surface, lines of sight and level distorted, objects thrown up into the air

SOURCE: http://www.ohiodnr.com/OhioSeis/html/scales.htm

Appendix B:
Explanation of Surficial Deposit Nomenclature

T = till
Ti = till (Illinioan in age)
SG = sand and gravel
SGd = undifferentiated outwash sand and gravel over ice contact or outwash units of mostly sand and
gravel, or deeply buried predominantly sand and gravel
IC = ice contact deposits; highly variable poorly sorted gravel and sand with inclusions of clay silt and till lenses
P = Pennsylvanian bedrock unit
SSh = Mississippian sandstone and shale bedrock units

( ) = patchy deposit
= indicates that the thickness of given deposit ranges between [(#*10)/2] and [(#*10) + (#*10)/2]
#- = indicates a channel fill deposit, with (#*10) being its maximum thickness and 0 being its minimum (as the channel shallows pinches out to zero)
/ = indicates that the surficial deposit unit to the left of '/' is on top of the unit to the right of the '/'

Example: (T2) / SG2 / SGd17- / P = patchy till deposit (10-30' thick, where present) over a sand and gravel deposit (10-30' thick) over an outwash/kame and esker deposit (from 0-170' thick) over a Pennsylvanian bedrock unit

Appendix C:
Explanation of Preliminary Surficial Deposit Nomenclature

<u>G3 Ground Moraine</u>
Flat to gently undulating silty clay tills. (Late Wisconsinan: Hayesville, Lavery Tills)
18 to 14 years before present

<u>G4 Ground Moraine</u>
Flat to gently undulating clayey tills. (Late Wisconsinan: Hiram Till)
18 to 14 years before present

<u>M3 End Moraine</u>
Occurs as hummocky ridges higher than adjacent terrain. (Late Wisconsinan: Hayesville, Lavery Tills)
18 to 14 years before present

<u>OU Outwash</u>
Undifferentiated, deposited by meltwater in front of glacial ice; occurs as valley terraces or low plains; sand and gravel, well sorted and stratified. (Late Wisconsinan)
23 to 13 years before present

<u>M1 End Moraine</u>
Occurs as hummocky ridges higher than adjacent terrain. (Late Wisconsinan: Loam till with thin loess cover)
24 to 18 years before present

Appendix D:
Summary of Figures

Figure A: Seismic stations in reference to the preliminarily calculated epicenter for the Alliance, Ohio earthquake of August 2000
Source: http://aamc.geo.lsa.umich.edu/Regional_Events/00Aug7.Ohio/00Aug7.html

Figure B: Map showing the epicenter of the Alliance earthquake superimposed over the Suffield and Smith Township Faults
Source: http://www.dnr.state.oh.us/OhioSeis/earthquakes/000806/feltmap.gif

Figure C: Map showing Transylvanian Fracture Zone
Source: Root, Samuel I. "Effect of the Transylvania Fracture Zone on Evolution of the Western Margin of the Central Appalachian Basin," Proceedings of the 8th International Conference on Basement Tectonics. Vol. 8, 1988, p. 470, Figure 1.

Figure D: Map of major Precambrian basement structures in Ohio
Source: http://www.dnr.state.oh.us/OhioSeis/images/faultbig.gif

Figure E: Glacial Deposits of Ohio
Source: Hansen, Michael. "The Ice Age in Ohio," Division of Geological Survey, Educational Leaflet No. 7, 1997.